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# Laboratory testing of process bus equipment and protection functions in accordance with IEC 61850 standard. Part I: Electrical arrangement and basic protection functions tests

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ABSTRACT

The use of process bus modern technology in accordance with the IEC 61850 protocol allows performing modern measurement and improving the protection automation system. It also allows for the integration and complex building of functional automation and control systems based on network devices in Ethernet technology. The paper presents measuring tests of a process bus equipment and the operation of protection functions based on measurements.



## 1. Introduction

The electrical power systems have become larger and more complex in the last 60 years due to the population growth and higher standards of living required by the society. The drawback of this situation is as follows - these complex systems are becoming more vulnerable to natural disturbances and external threats. After analyzing the detailed anatomy of the blackouts which have occurred since 1965 [1], it becomes evident that protection played a significant and crucial role. On one hand, the advent of computerized relays, global positioning systems (GPS), phasor measurement units (PMUs) [2–5], power-electronic control devices [6–13], digital communication technologies [14,15], and other technical developments [16–19] have facilitated improved protection of power systems over a wide area. As a result, the monitoring, control, protection, and automation of the power systems in real time are becoming more effective.

The standard IEC 61850 [20], elaborated by working groups of the Technical Committee 57 of IEC (IEC TC57), has standardized communication in substations using both state of-the-art communication technology and powerful object modeling with high-level engineering support. This standard allows the introduction of high-speed data technology of measuring devices, implementing and operating decision-making in the modern power energy sector. For many years, the data transmission problem enters more deeply into the field of substation automation systems [24,25], including protection systems. Currently, the standard IEC 61850 is one of the main levers for the implementation of this type of solution [21–23]. It provides the ability to quickly transfer data between measuring, decision-making and actuating devices, which operate in the substation secondary circuits. Such solution will be used to transfer any type of data (including sampled data from analog current and voltage transformers) using high-speed serial interface. This standard allows integrating three levels of operation: the level of the substation, the field level and the process level [20,21]. The substation level has an User Interface (UI) computer and gateways (GW), which are used to connect substation control center to WAN. In order to prevent cyber attack from outside and to ensure the integrity of the data in the substation firewall facilities should be provided. They also secure the information flow with remote network control centers or System Control and Data Acquisition (SCADA). To connect with other substations and SCADA working with other SAS protocols, e.g., DNP (Distributed Network Protocol) or Modbus, the gateway needs to implement protocol conversion functionality or should cooperate with separated protocol conversion systems. The process level has direct connection with the

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**Nomenclature**

| | | | |
|---|---|---|---|
| IEC | International Electrotechnical Commission | CB | circuit breaker |
| CT | Current transformer | TOC | Time delayed overcurrent protection |
| IED | Intelligent electronic device | IOC | instantaneous overcurrent protection |
| WAN | wide area network | DUT | device under test |
| SCADA | System Control and Data Acquisition | | |
| PT | power transformer | | |

switchyard equipments e.g. CTs, PTs, CBs and Switches, etc. All these levels are connected to one another through the above-mentioned devices and the substation communication system, working together using the same telecommunications standard.

Conventional protection IEDs have a hardware architecture that includes analog and binary (opto) input modules, as well as relay outputs. Analog input modules convert the secondary currents and voltages into digital samples transferred over an internal to the IED data bus to the processing module of the IED. The different sampled or calculated values are then used by the individual functional elements or schemes in such a way that may lead to the operation of the device and activation of one or more relay outputs [22]. The testing of conventional protection devices has some similarities and some differences with the IEC 61850 communications based solutions. In the case of conventional testing procedure the testing device has to simulate the substation process through hard-wired interface between the analog and binary outputs of the testing device and the analog and binary inputs of the device under test (DUT). At the same time the testing device has to monitor the closing of relay outputs of the DUT in order to detect the operation of the IED, analyze it in order to determine if the performance meets the specifications. In case of partial implementation of IEC 61850 communications in the tested IED, the multifunctional IED interfaces with the process in a similar way to the conventional method described above, i.e. hard wired analog signals are established to exchange data between the DUT and the testing device. The communication-based distributed functions in this case use IEC 61850 GSSE or GOOSE messages [24,25]. All devices with communication interfaces have to be connected to the substation network [20].

One example of this technology is the system HardFiber of General Electric. "A process bus system is a remote I/O architecture for protection, control, monitoring and metering allowing designing out copper wiring in substation switchyards and replacing it with standardized optical fiber based communications" [26]. The HardFiber consists of a measuring device called the BRICK, an optical switch called Cross Connect Panel and a and digital input module for the protection relay of UR series called process card. The arrangement of the HardFiber devices is presented in Fig. 1.

In this system, the BRICK device, as shown in Fig. 2 is composed of four independent microprocessor systems with independent optical Ethernet ports, which can exchange data using the IEC61850 protocol. Each system performs analog measurements, digital signal reception, digital signal generation and data exchange. The BRICK device is connected to the CT secondary circuit by a dedicated cable with copper conductors terminated by many special hermetic connectors. Similarly, all of the secondary devices signals are fed to the digital inputs of the BRICK device and digital outputs of the device signals are connected through dedicated connectors having a different shape and number of pins. Each BRICK device optical port exchanges data over dedicated optical fiber placed along with two copper wires that provide power to the prefabricated, reinforced cable. Fiber optic connectors are placed on the optical distribution frame connectors, where they can be combined with the use of patch cords to one of the four ports of optical card protection relay process card as shown in Fig. 2. Each of the four processors of the BRICK device can therefore work with a protective device, which transmits control signals in order to determine the instants of sampling. This mechanism

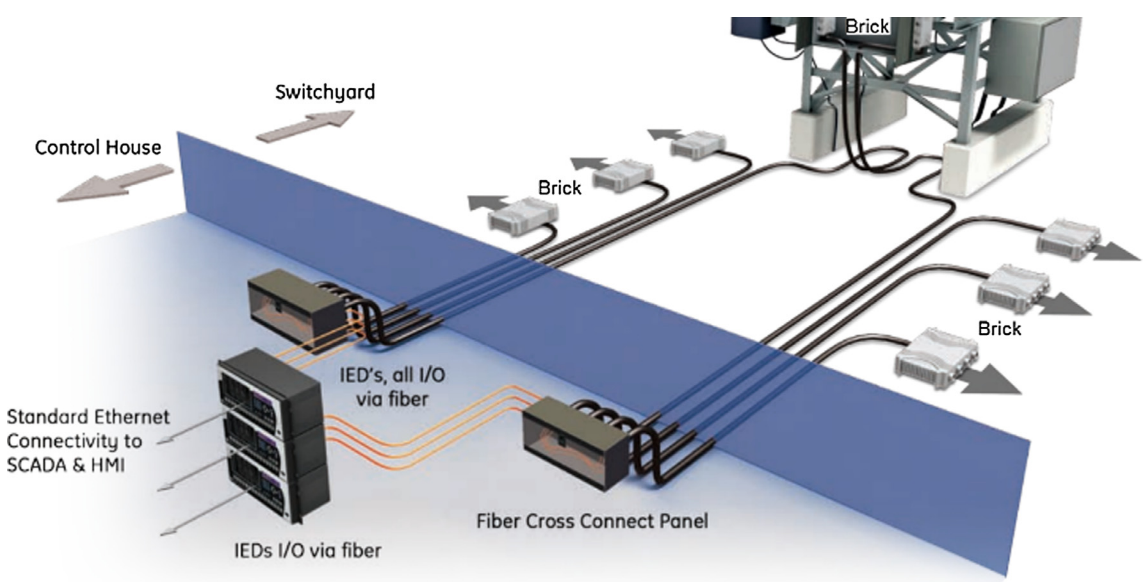


**Fig. 1.** Arrangement of the HardFiber devices (above) [25].